THE ^{53}MN - ^{53}CR ISOTOPE SYSTEM IN THE OMOLON PALLASITE AND THE HALF-LIFE OF ^{187}RE.

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We have recently reported the results of our studies of ^{53}Mn - ^{53}Cr isotope systematics in various objects in the solar system: angrites, chondrites, eucrites, Mars, and the Moon [1]. These studies are based on high precision measurements of the abundances of the ^{53}Mn decay product - ^{53}Cr ($T_{1/2}$ of ^{53}Mn is 3.7 Ma). The results showed that the relative abundance of the radiogenic ^{53}Cr is a function of the radial distance from the Sun. This gradient may either be due to an early radial Mn/Cr fractionation in the nebula or, at present more likely, an original ^{53}Mn heterogeneity. To extend the ^{53}Mn - ^{53}Cr systematics to another meteorite class we have studied the pallasite Omolon. Another reason for our investigation of a pallasite was to combine the chronological information which is provided by the ^{53}Mn - ^{53}Cr isotope system with the ^{187}Re-^{187}Os isotope data for pallasites [2] as an attempt to obtain a better constraint for the decay constant of ^{187}Re. The directly measured value of 1.64 x 10^{-11} a^{-1} [3] which is currently in use has an uncertainty of 3%. The recently refined values of $\lambda(^{187}$Re) of 1.66 x 10^{-11} a^{-1} [4] and of 1.666 x 10^{-11} a^{-1} [5] seem to be more accurate but they are based upon assumptions pertaining to the absolute ages of iron meteorites and may require further refinement.

We have measured ^{53}Cr/^{52}Cr, and Mn and Cr concentrations in chromite (Chr) and in two olivines (Olv 1, Olv 2). All three samples show excess ^{53}Cr. The measured ^{53}Cr/^{52}Cr ratios, expressed in ε units (1 part in 10^4), and the ^{55}Mn/^{52}Cr ratios are shown in the Figure. The excesses of ^{53}Cr in the olivines are corrected for a small spallation contribution which is calculated from the direct measurement of the spallation Cr isotopic composition in the adjacent metal phase.

The ^{53}Cr excesses (Figure) are correlated with the respective ^{55}Mn/^{52}Cr ratios and the data points form an isochron whose slope defines a ^{53}Mn/^{55}Mn ratio of (1.29±0.19) x 10^{-6} at the time of isotopic closure. At the chondritic ^{55}Mn/^{52}Cr ratio of 0.76 the corresponding excess of ^{53}Cr is ~0.52 ε.

Within normal uncertainties (5-10 ppm) this value is the same as that in chondrites (~0.48 ε) and as that calculated from the ^{53}Mn - ^{53}Cr systematics in the angrites (~0.48 ε). If this agreement is not coincidental, this suggests that the pallasite source material had a chondritic Mn/Cr ratio. It also indicates that there is no detectable heterogeneity of ^{53}Mn between the chondrite, angrite, and pallasite parent bodies. Moreover, our new data on the ^{53}Mn - ^{53}Cr isotope systematics in diogenites and cumulate eucrites combined with ordinary eucrites [6] show that the difference in the original ^{53}Mn abundances between the HED parent body and chondrites is, if it exists at all, much smaller than was suggested by the eucrite data alone [1]. Thus, for samples from the asteroid belt measured so far there does not appear to be any significant heterogeneity of ^{53}Mn and, therefore, the ^{53}Mn - ^{53}Cr chronometer can be used to date objects and processes within the asteroid belt.

The ^{53}Mn/^{55}Mn ratio of (1.29±0.19) x 10^{-6} in Omolon is essentially the same as that in the angrite LEW86010 (LEW) (updated value: (1.25±0.07) x 10^{-6}). Omolon is thus 0.2±0.9 Ma older than LEW. The absolute Pb-Pb age of LEW is 4557.8±0.4 Ma [7]. Converting the relative age of Omolon into an absolute age we obtain 4558.0±1.0 Ma. Although metallographic cooling rates for pallasites indicate extremely slow cooling at low temperatures (~1C°/Ma, e.g. [8]), the isotopic closure of the ^{53}Mn - ^{53}Cr isotope system in Omolon olivines and chromites at 4558.0±1.0 Ma is consistent with a much faster cooling rate (50-100 C°/Ma) at least in the high-temperature range.

It was shown in [2] that the ^{187}Re-^{187}Os isotope data for pallasites are consistent with those for IIAB irons: the data points for the pallasites fall along the well-defined IIAB whole-rock isochron with a slope of 0.07848±0.00018. Assuming that the formation of Omolon was contemporaneous with that of the other pallasites and that the Re-Os system in the metal closed at the same time as

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Mn-Cr in Olv and Chr, using a slope of 0.07848±0.00018 and an absolute age for Omolon of 4558.0±1.0 Ma we calculate a decay constant $\lambda(^{187}Re) = (1.658\pm0.003) \times 10^{-11}$ a^{-1}. This value, presently our best estimate with an uncertainty of only ~0.2%, is 1.1% higher than the direct experimental determination [3] and agrees well with the value of 1.66×10^{-11} a^{-1} [4]. In a more recent compilation [9] it was shown that the slope for the pallasite data may be slightly lower (0.07804±0.00025) than that for IIABs resulting in $\lambda(^{187}Re) = (1.649\pm0.005) \times 10^{-11}$ a^{-1}. However, there still is a dilemma when the steeper slope for the combined IVA+IVB Re-Os data [4] is considered. If this were a true primary feature then $\lambda(^{187}Re)$ could be as high as 1.669×10^{-11} a^{-1} and we would be forced to conclude that the Re-Os system in the pallasites closed considerably later than the Mn-Cr system. We note, however, that the slopes for IVA and IVB obtained by [4] are not in agreement with those in [5]. It also has to be noted that the uncertainties in $\lambda(^{187}Re)$ calculated here do not include the uncertainty of the Os tracer calibration (~1.6% [4]) which, at present, is a limiting factor for the refinement of the absolute precision of the ^{187}Re-^{187}Os dating method.

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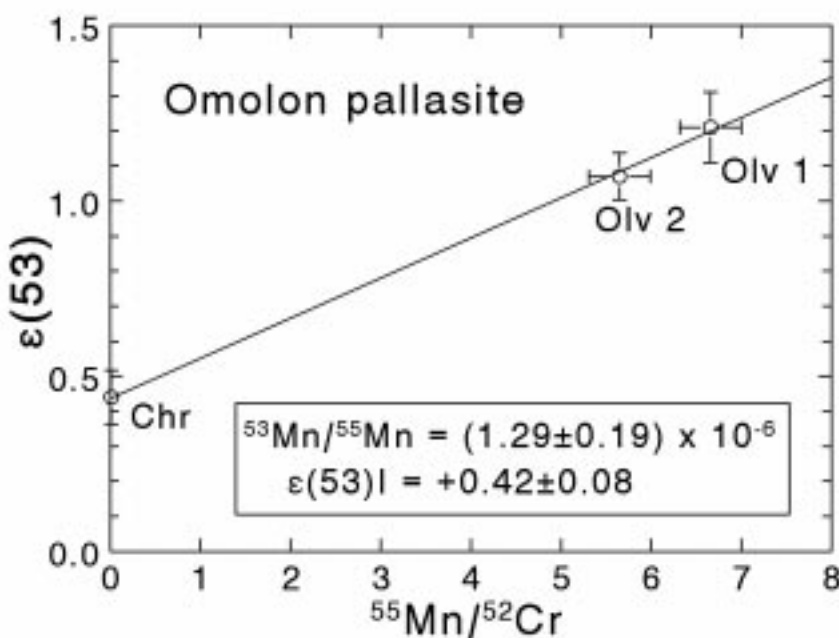

Figure: The ^{53}Mn - ^{53}Cr isotope system in the pallasite Omolon. The excesses of ^{53}Cr relative to the terrestrial value are expressed in ε units (1 part in 10^4). The variation of $^{53}Cr/^{52}Cr$ with $^{55}Mn/^{52}Cr$ indicates that ^{53}Mn was still extant at the time of solidification of this meteorite. The slope of the best fit line defines a $^{53}Mn/^{55}Mn$ ratio of $(1.29\pm0.19) \times 10^{-6}$ at that time. The difference between the $^{53}Mn/^{55}Mn$ ratio in Omolon and in the angrite LEW86010 corresponds to a time difference of 0.2±0.9 Ma. This, combined with the absolute Pb-Pb age of LEW86010 of 4557.8±0.4 [7], yields an absolute age for Omolon of 4558.0±1.0 Ma.